Ventana™ Optical Train: a high-performance off-the-shelf HCPV optics solution

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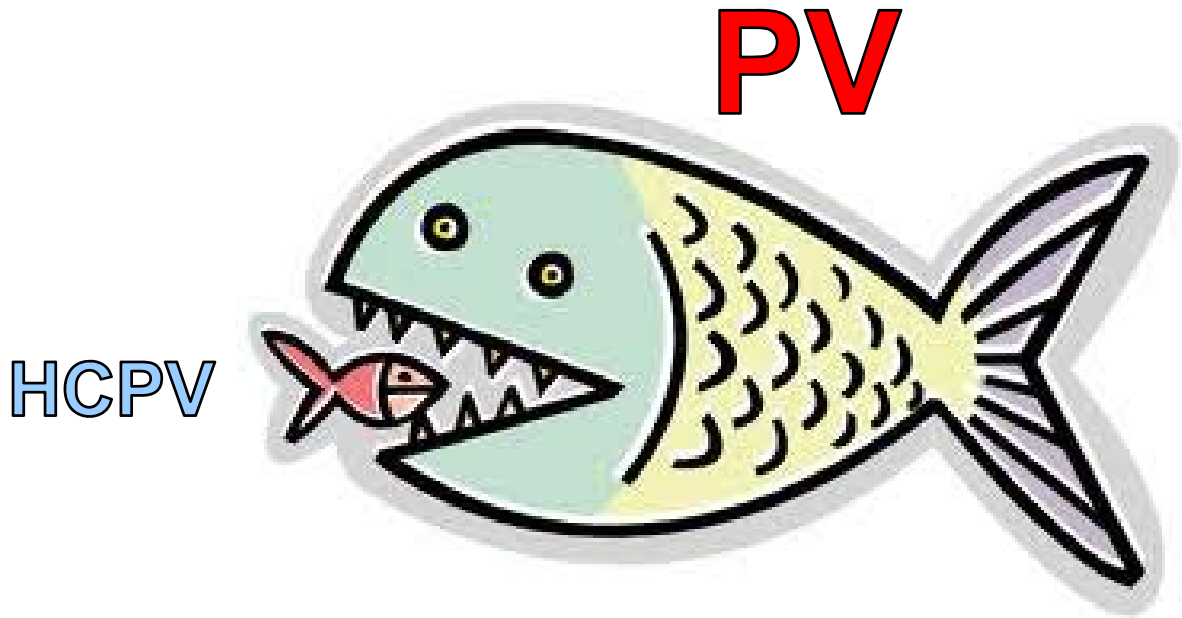
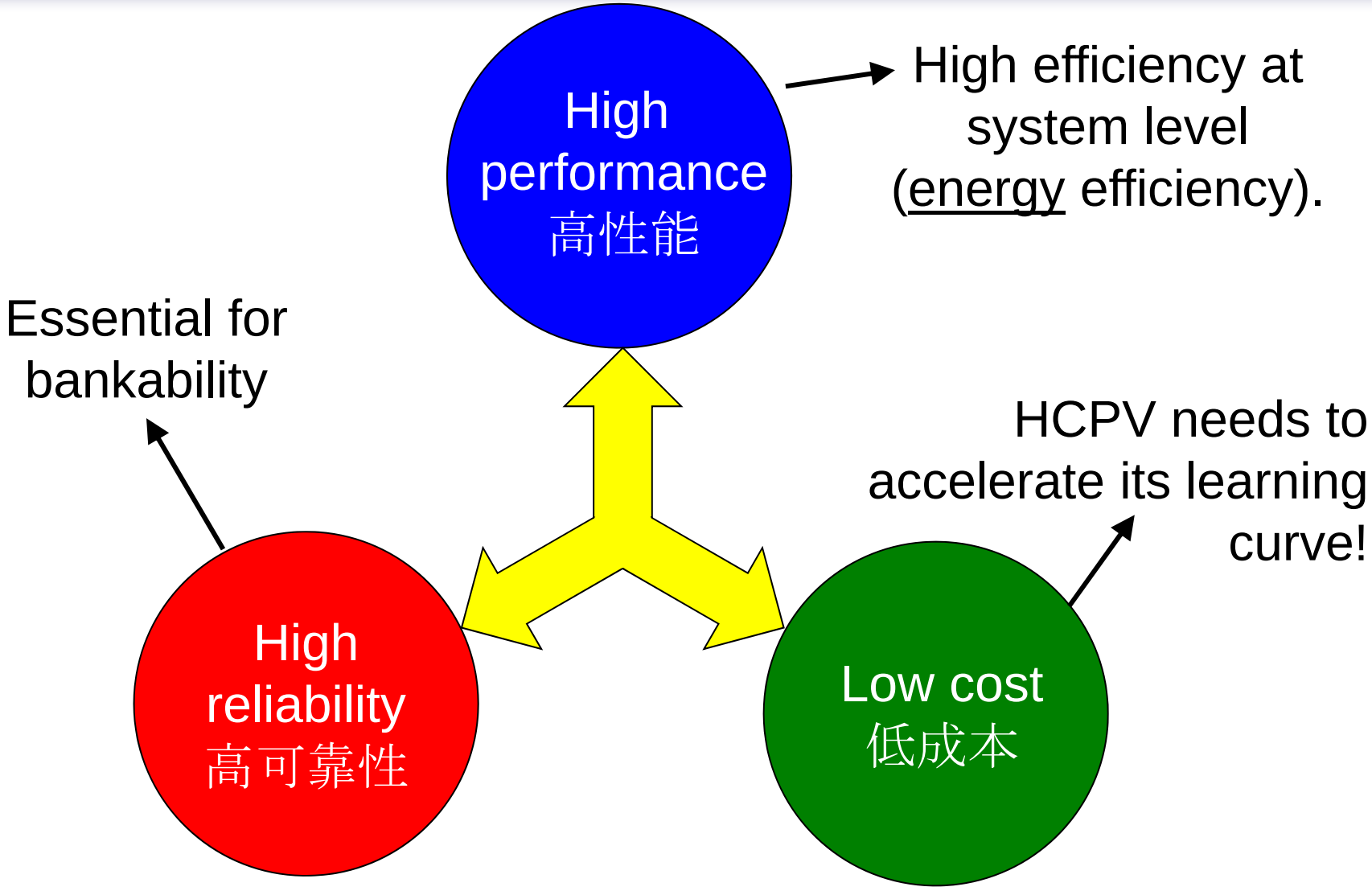
- Ventana™ cost
- Ventana™ performance
- Ventana™ reliability
- Conclusions

Who is our real competitor?



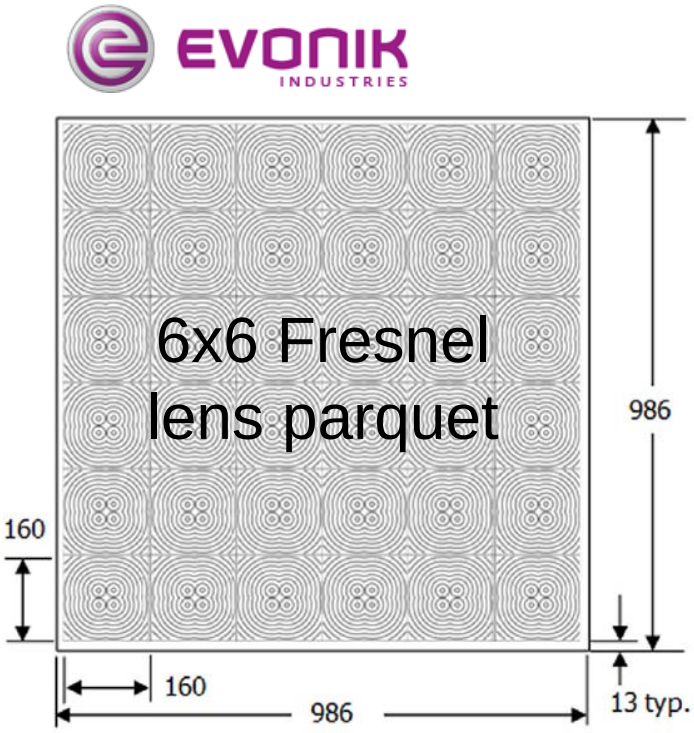
- PV and HCPV compete in the utility market
- PV cost reduction has been dramatic through volume

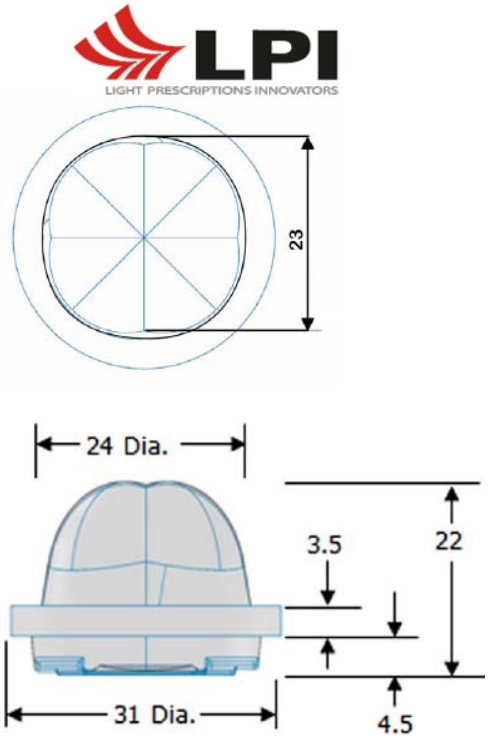
The key for HCPV success



The Ventana™ Optical Train

- A complete off-the-shelf optics solution by Evonik and LPI
- Based on the best-in-class design: The FK concentrator





POE = primary optical element

SOE = secondary optical element

The Ventana™ Optical Train

- A complete off-the-shelf optics solution by Evonik and LPI
- Based on the best-in-class design: The FK concentrator

Optical Train Efficiency (*POE*+*SOE*)	>83%
f # (diagonal aperture/height)	~1
Acceptance Angle*	±1.1°
POE Lens Size (mm2)	160 × 160
Cell Illuminated Area (mm2)	5 × 5
Geometrical Concentration	1024×
Module Efficiency**	>32%

*see next slides **with 39% efficient solar cell and no AR coatings

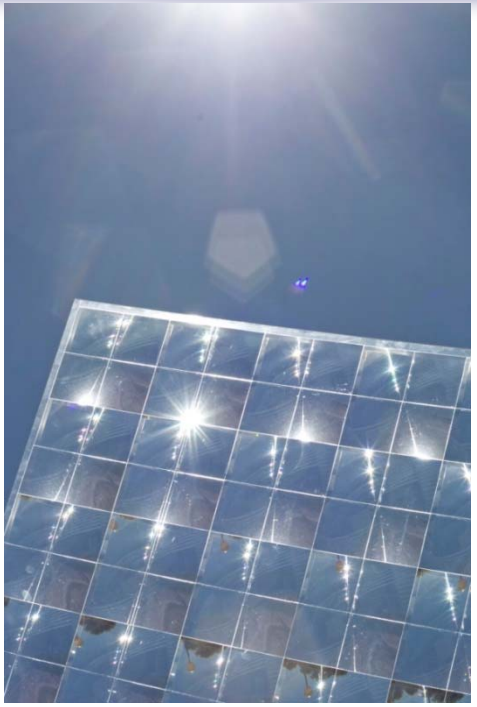
The Ventana™ Optical Train

POE:

- Available in PMMA by Evonik
- In SoG, coming soon

SOE:

- Available from LPI in B270-equivalent glass made by molding
- Available in Evonik Savosil™ silica glass made by sol-gel process



Ventana™ features

1. Geometrical concentration: 1,024×
2. Low cost of optics

Low cost
低成本

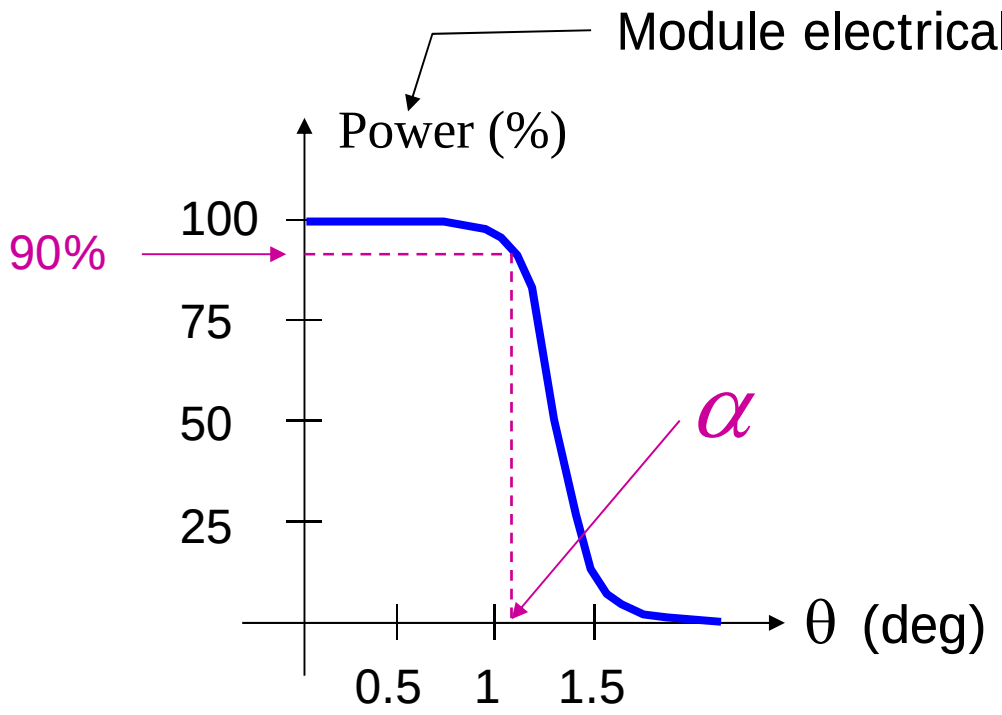
3. High acceptance angle (±1.1deg)
4. High optical efficiency (>83%)
5. Excellent irradiance uniformity

High performance
高性能

6. Durable materials
7. Compatible with excellent cell protection

High reliability
高可靠性

Acceptance angle definition



$C = 1{,}024\times$

$\alpha = \pm 1.1$ deg

- For a given architecture, the product $C \times \sin^2\alpha \approx$ constant
- The FK optics could provide
  - $\alpha = \pm 0.75°$ for $C \approx 2{,}000\times$
  - $\alpha = \pm 1.4°$ for $C = 600\times$

Why acceptance angle is so important?

The acceptance angle is a common basis to measure the tolerance of a design

Tolerance budget has to be shared among:

1. Sun's angular extension ±0.27
2. Optical components manufacturing (shape and roughness)
3. Module assembling
4. Array assembling, series connection mismatch
5. Tracker structure stiffness
6. Tracking accuracy

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- Ventana™ performance
- Ventana™ reliability
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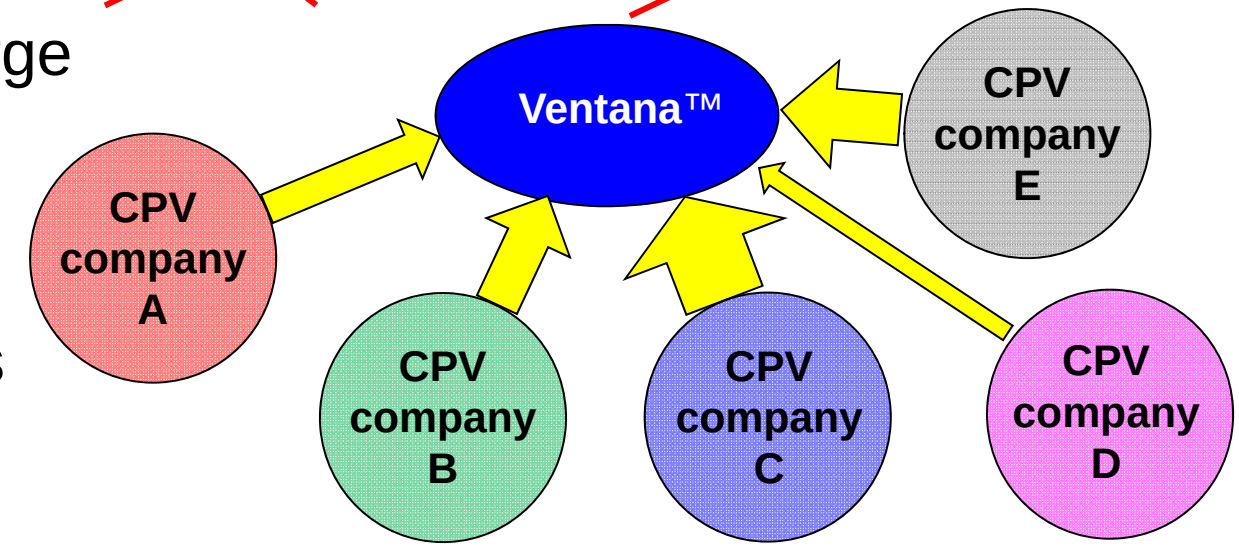
The Ventana™ cost (成本)

- High acceptance angle allows to reach a low system cost without compromising efficiency
- High concentration lowers the solar cell cost contribution
- Module manufacturers using **Ventana**™ eliminate:

~~Design costs~~ ~~Tooling costs~~ ~~Long lead times~~

- By producing large volumes for multiple customers, production costs are lowered



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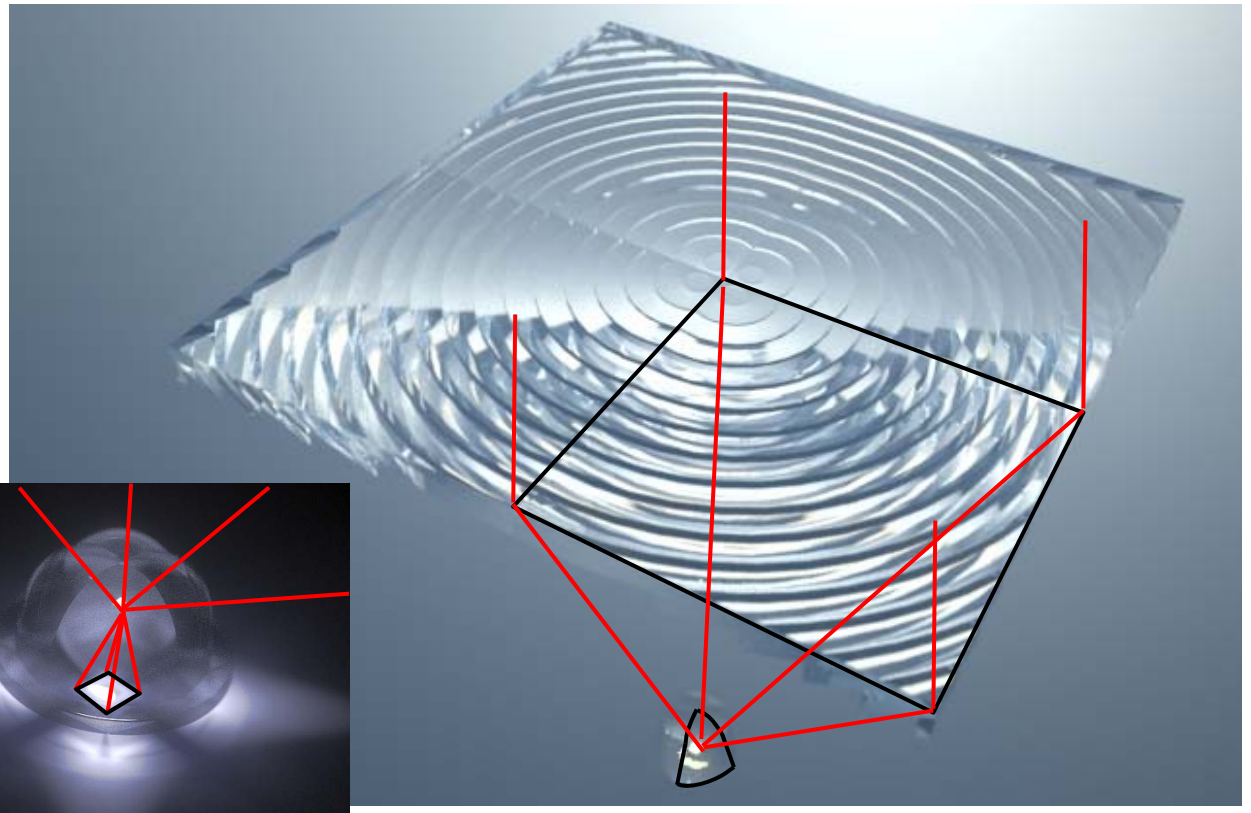
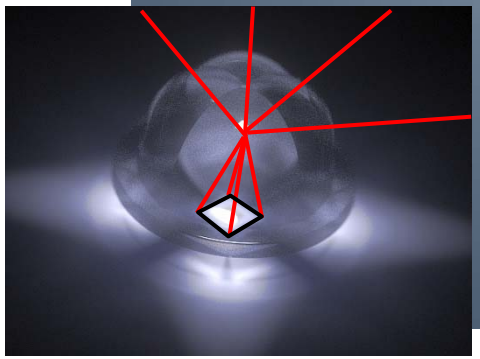
The Fresnel-Köhler (FK) concentrator

The FK is an advanced nonimaging concentrator using LPI proprietary 4-channel Köhler homogeneization



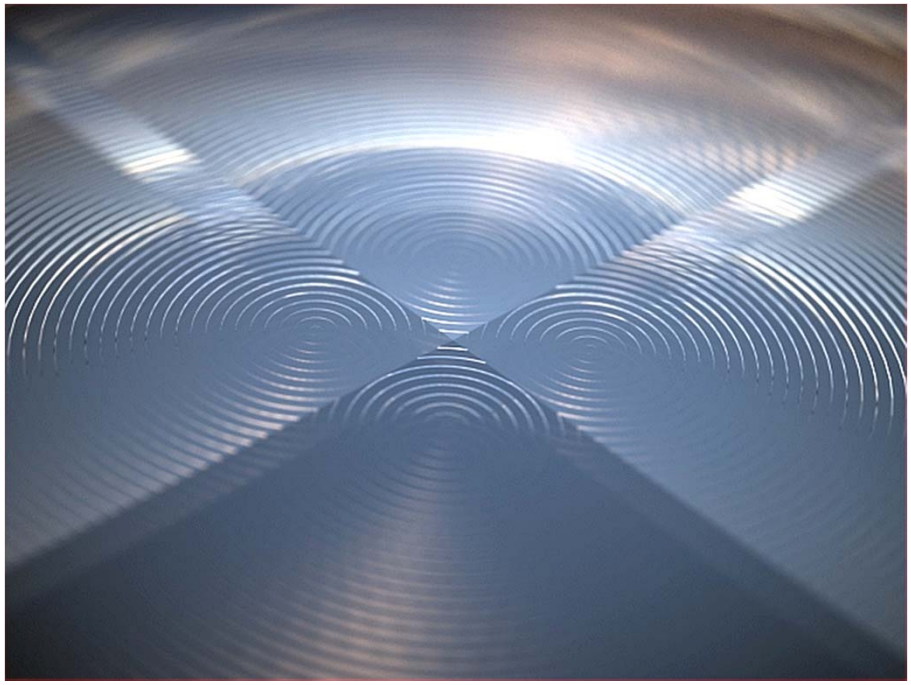
Free-form lens



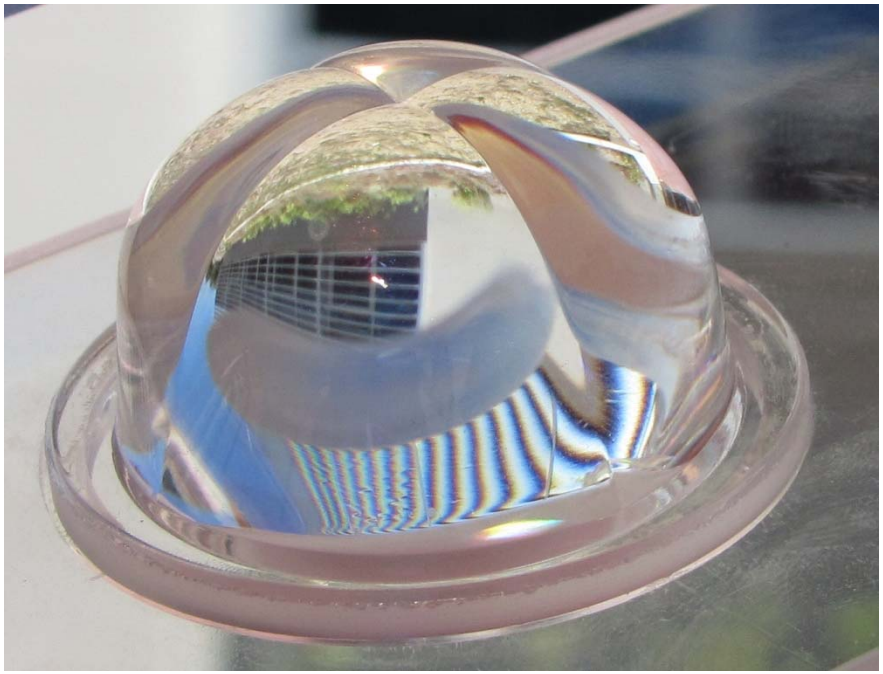
US Patent 8,000,018 and international patents pending

The FK concentrator

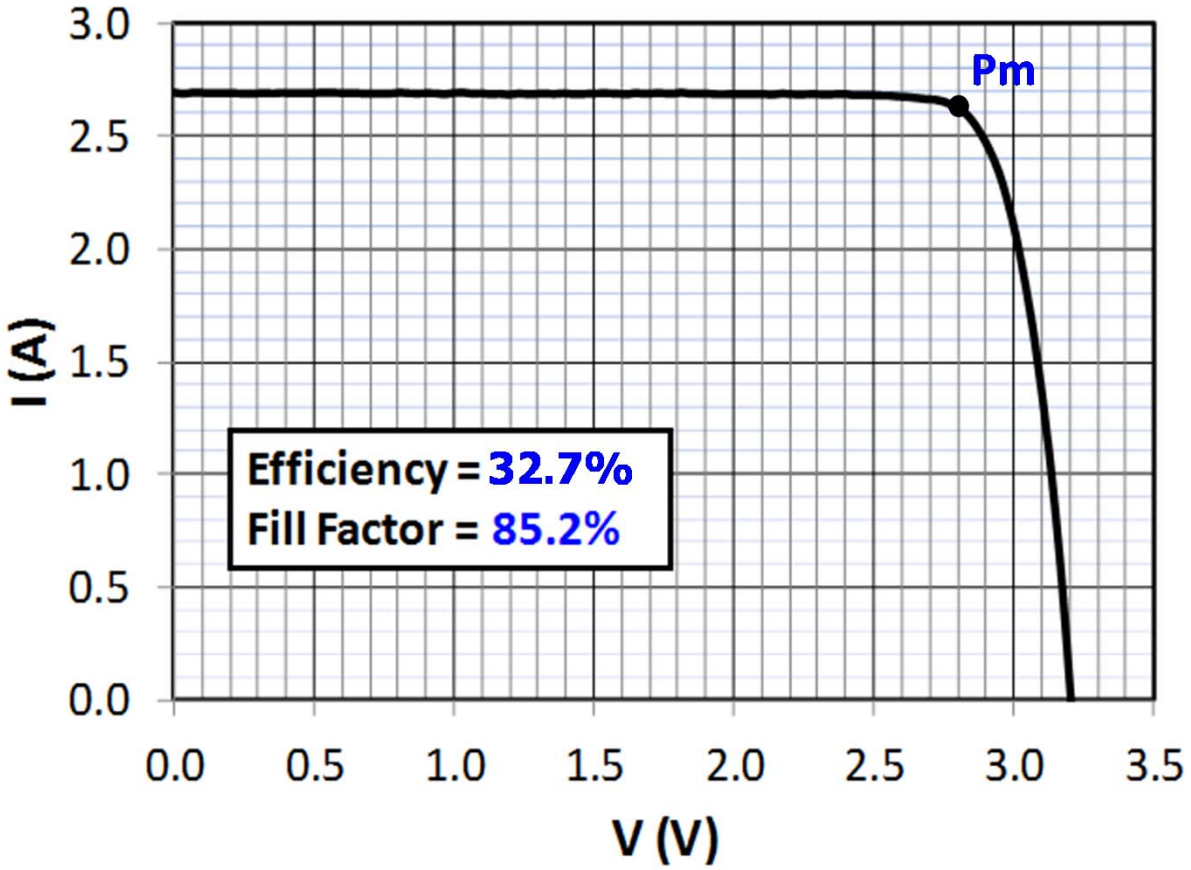
Fresnel lens



Freeform secondary lens

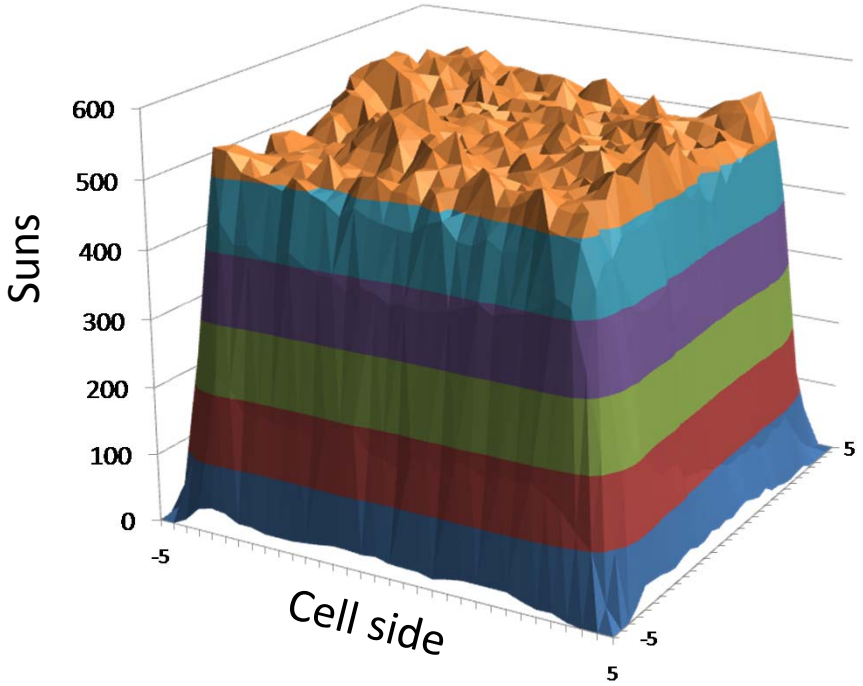


Ventana™ electrical efficiency

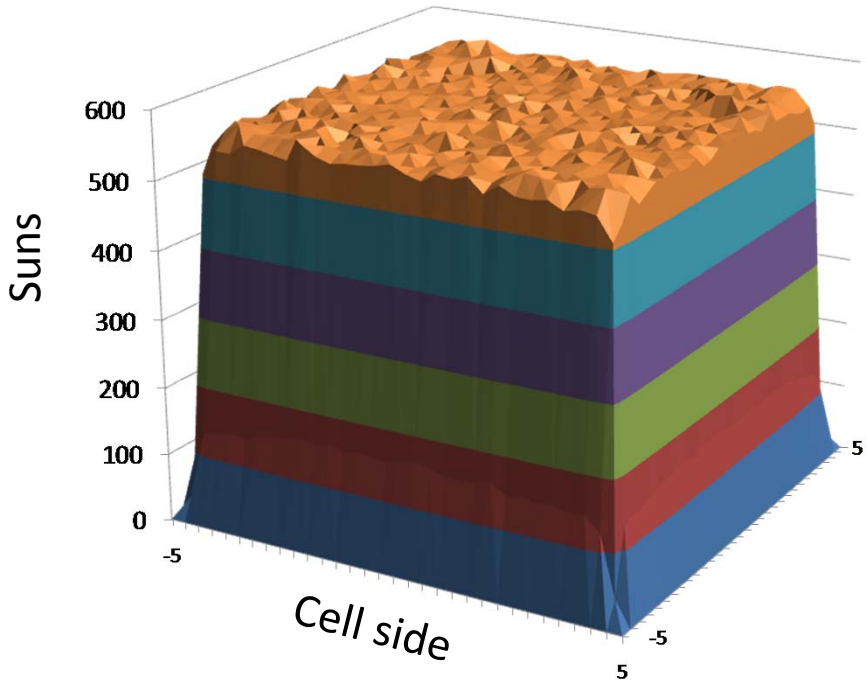


*Using a 39% efficient cell; no AR coatings; @Tcell=25ºC

FK irradiance uniformity

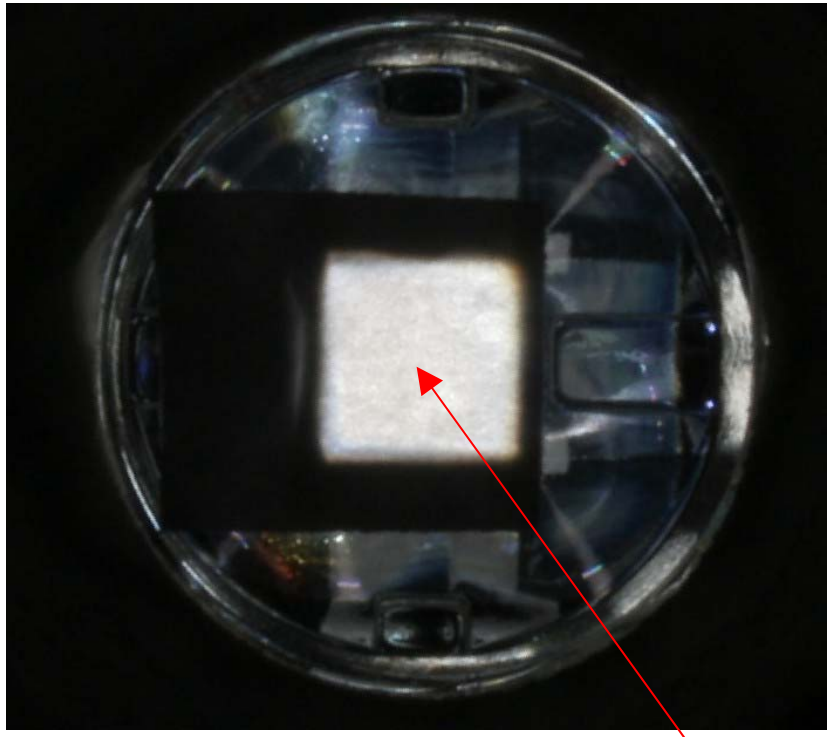


Measured



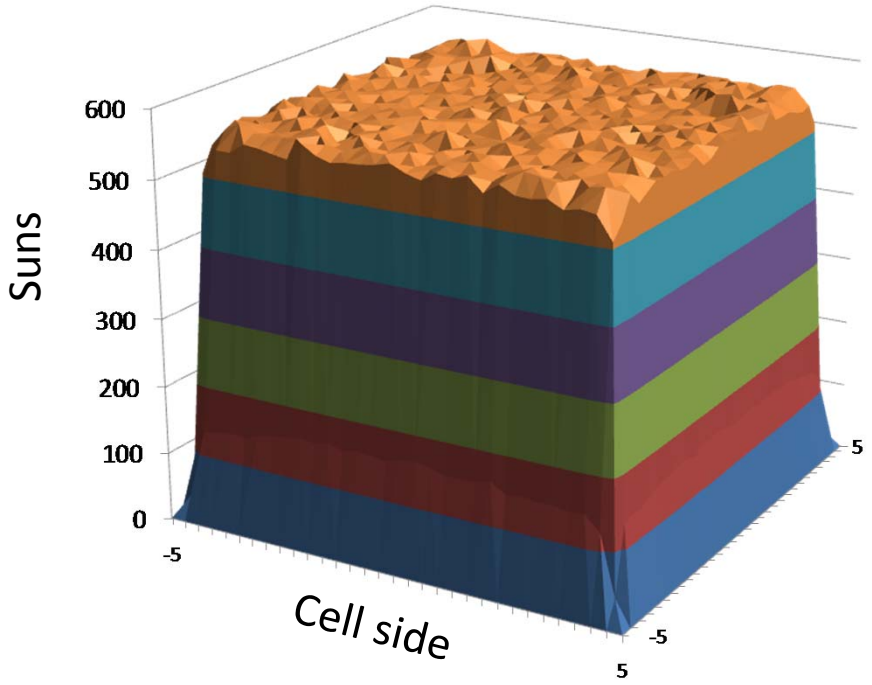
Simulated

FK irradiance uniformity



Suns

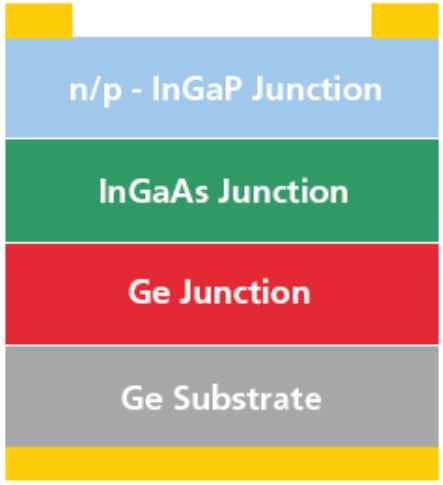
Measured



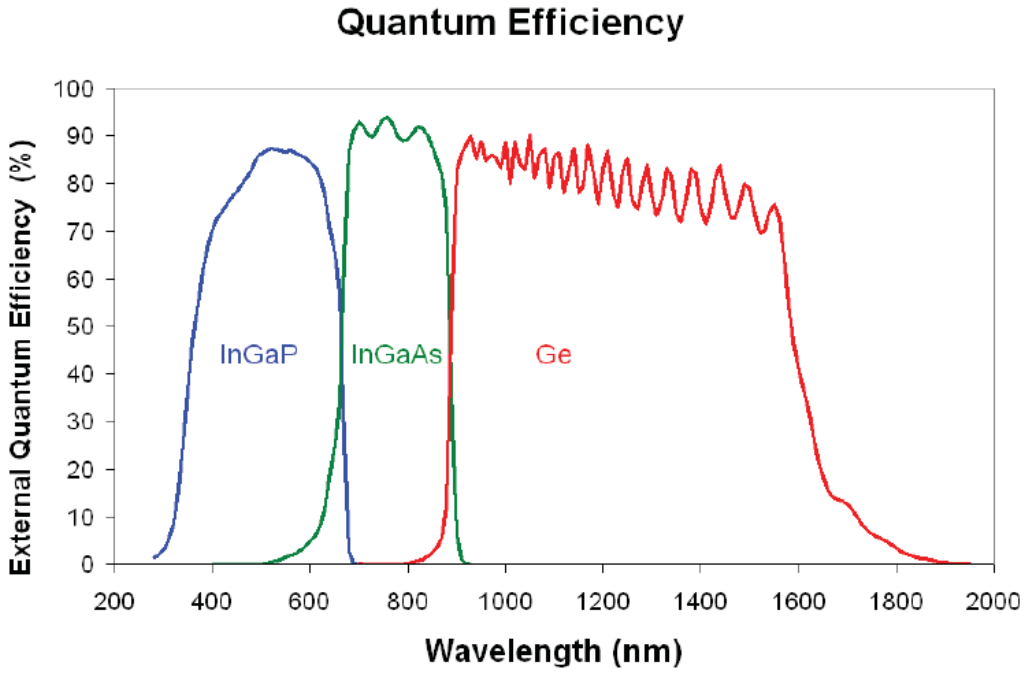
Simulated

No chromatic aberration on the cell!

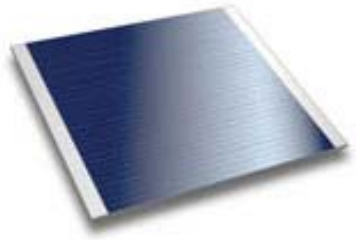
Ventana™ irradiance uniformity

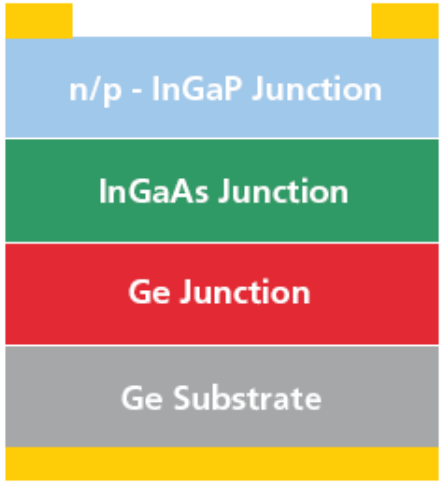


Cell Structure Diagram
(Tunnel diodes not shown)



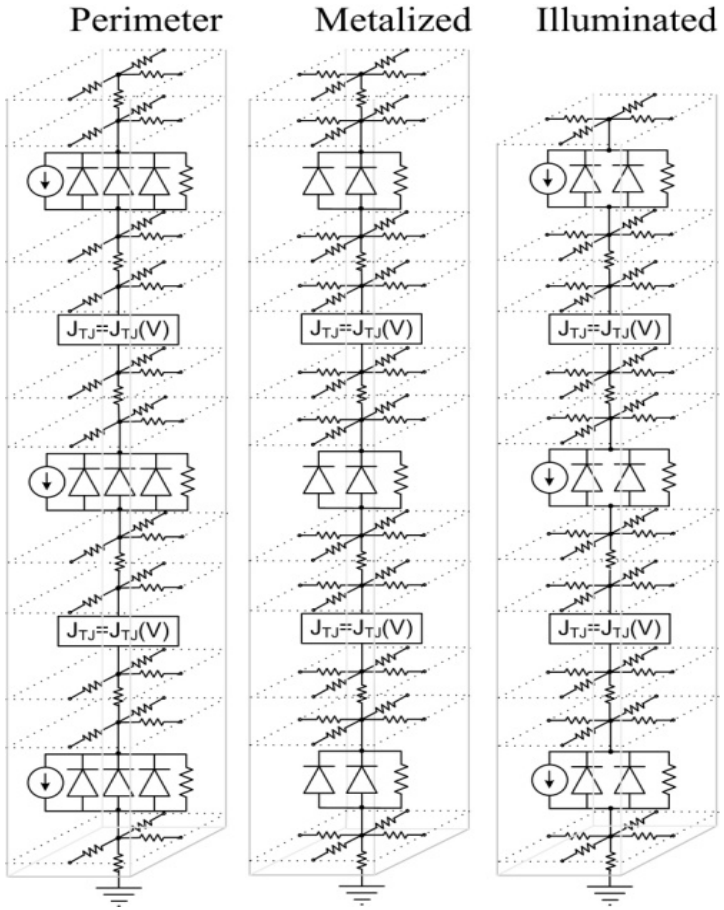
Ventana™ irradiance uniformity





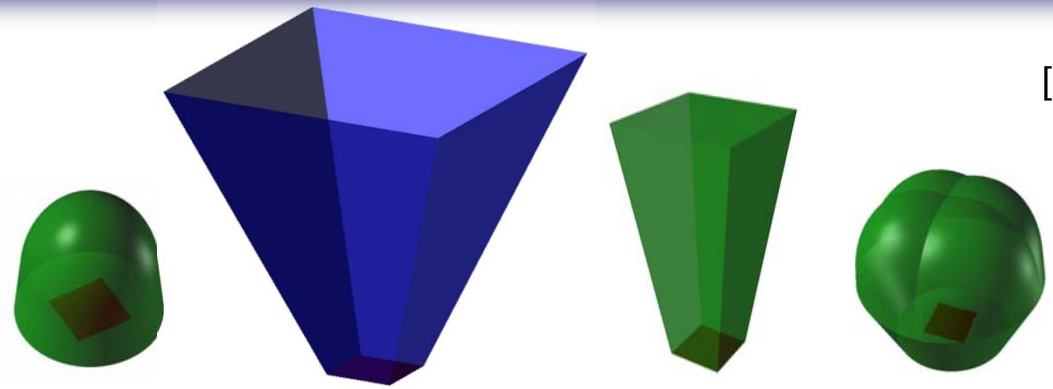
Cell Structure Diagram
(Tunnel diodes not shown)

[P. Espinet et al. CPV-8, Toledo, 2012]

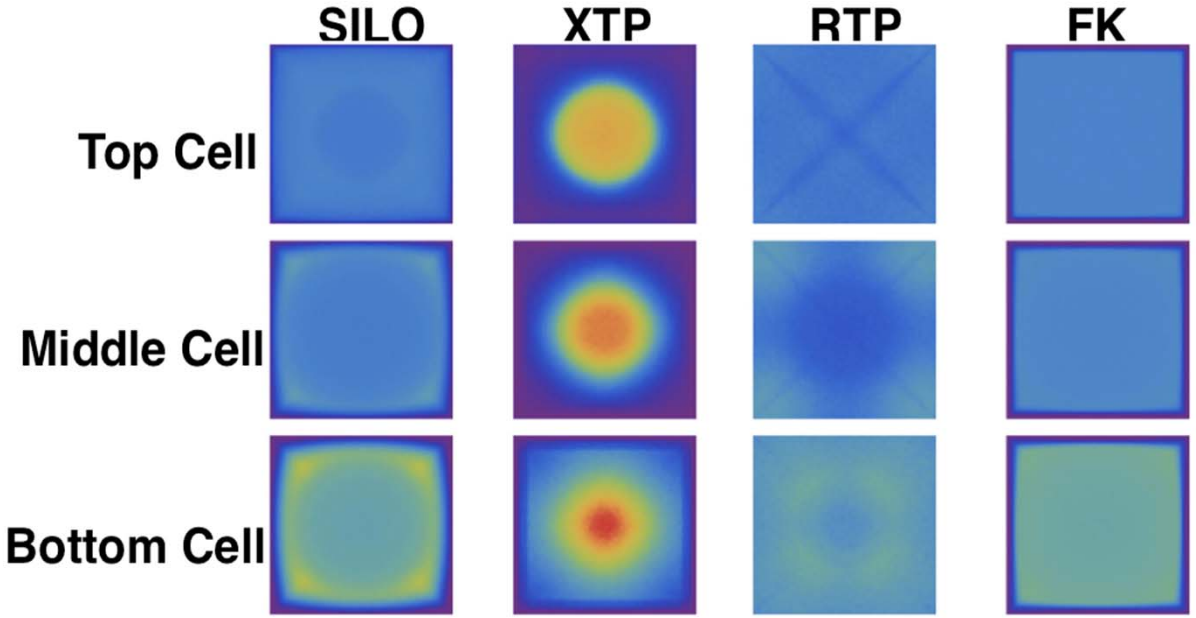


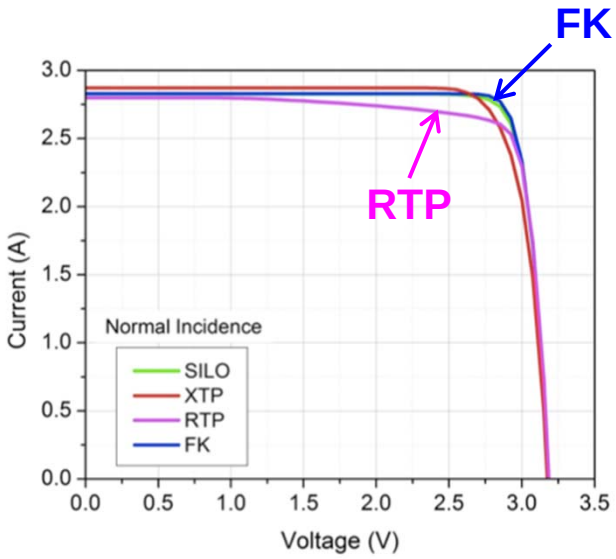
Ventana™ irradiance uniformity

[P. Espinet et al. CPV-8, Toledo, 2012]



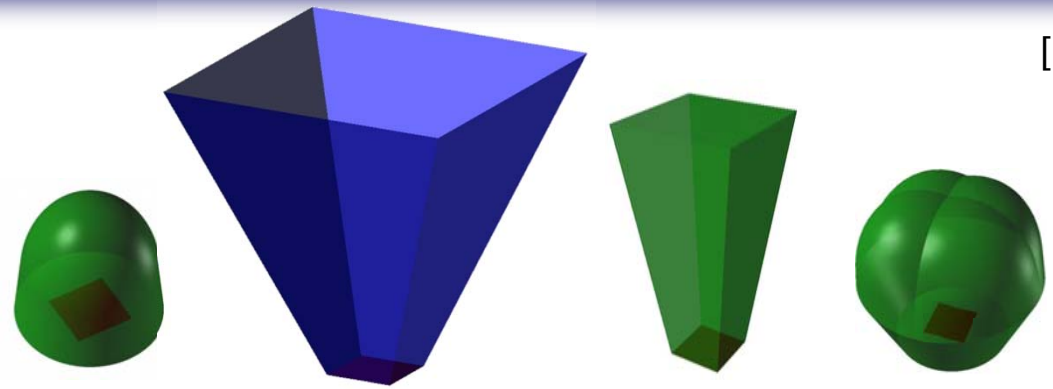
Tracker angle = 0º



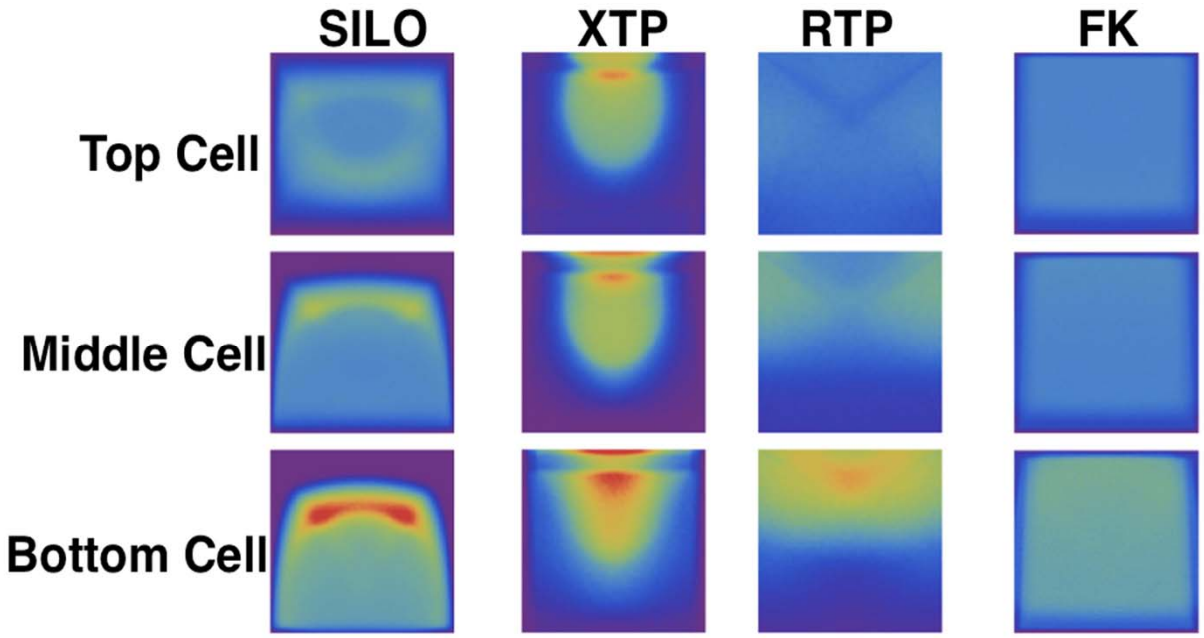


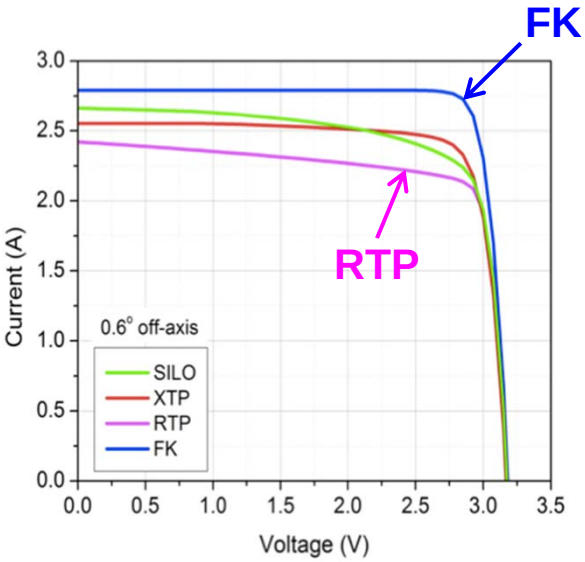
Ventana™ irradiance uniformity

[P. Espinet et al. CPV-8, Toledo, 2012]



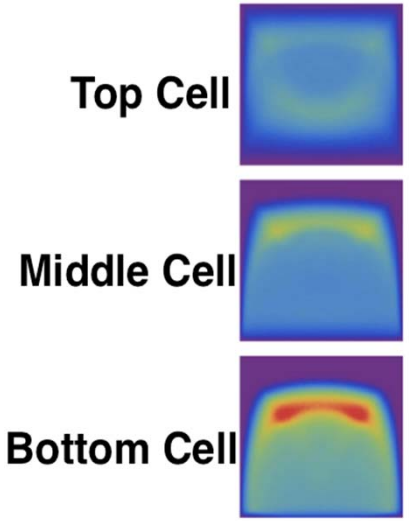
Tracker angle = 0.6º

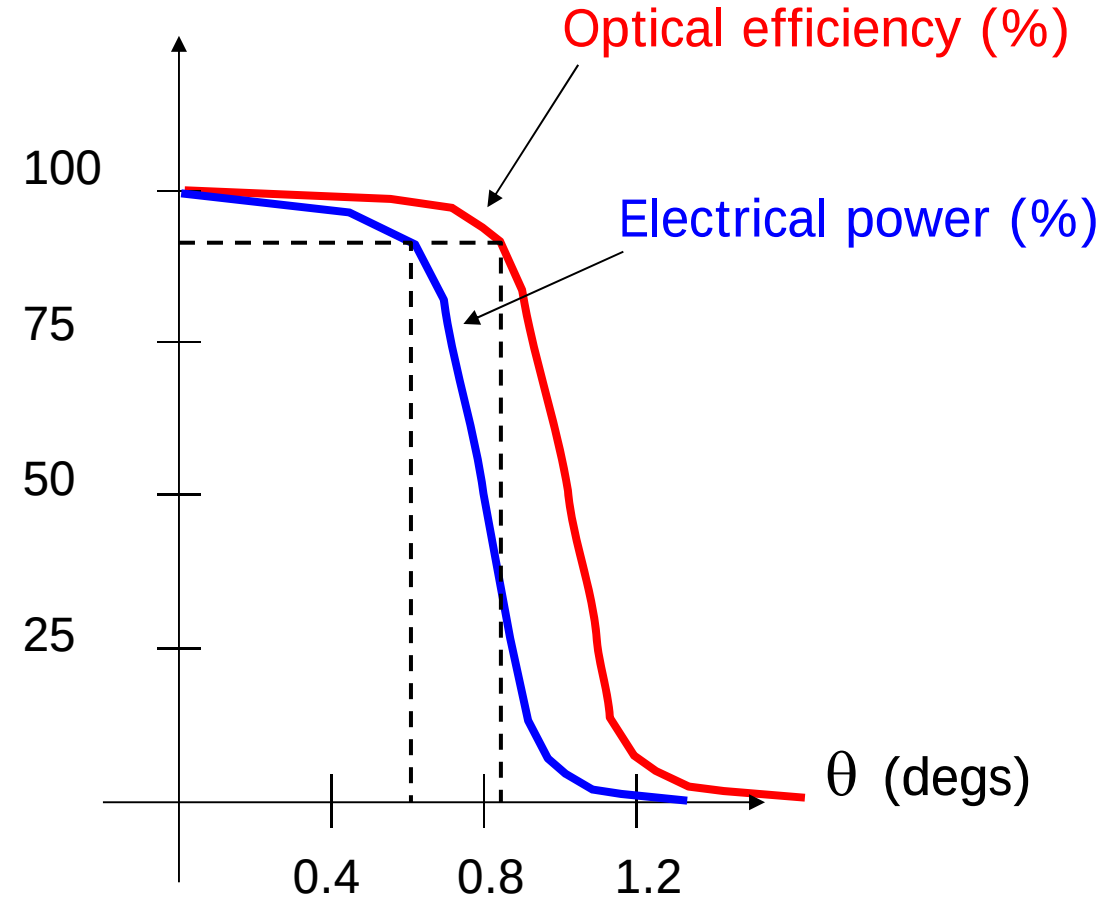




Acceptance angle definition

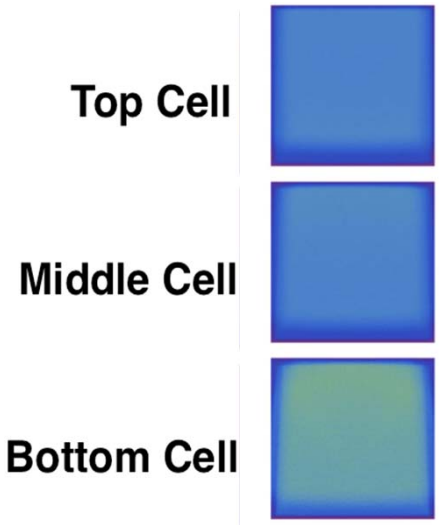
Other designs

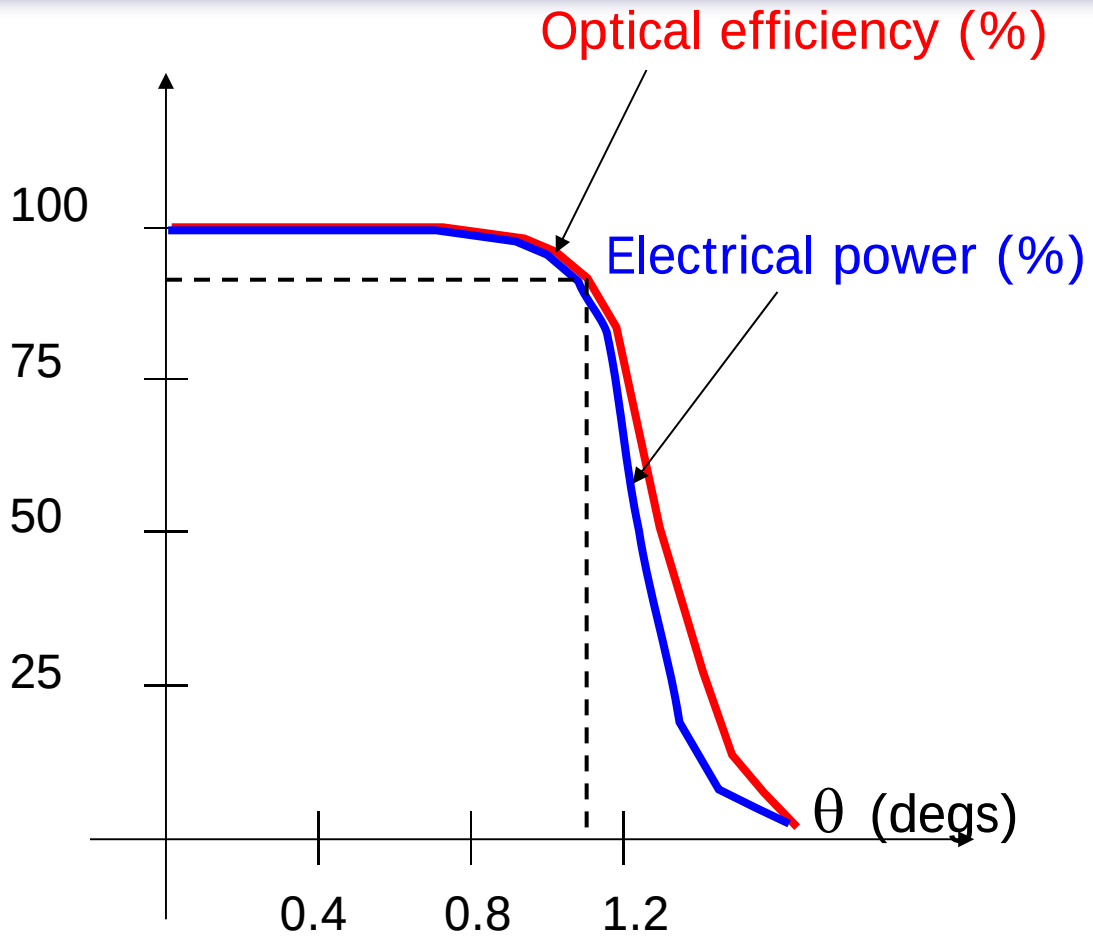




Acceptance angle definition

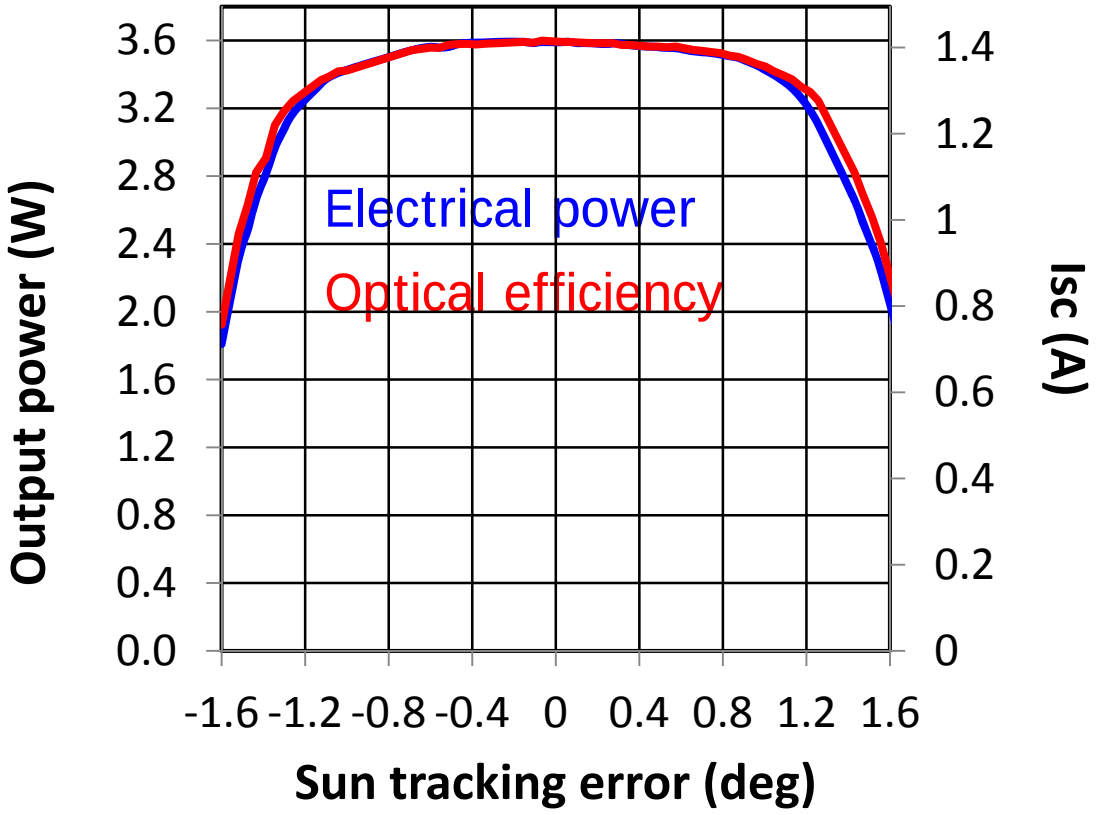
FK





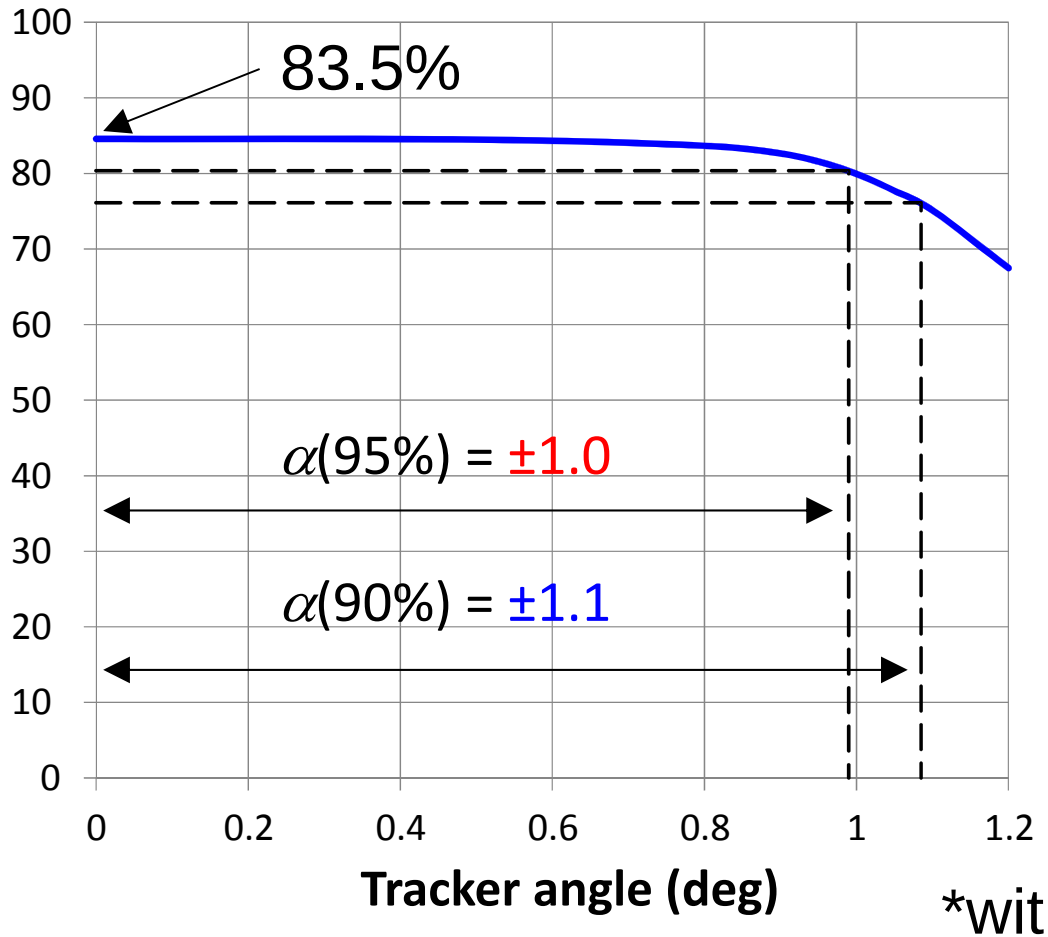
Acceptance angle definition

Measurements have confirmed those simulations



[P. Zamora et al. Journal of Photonics for Energy (2012)]

Ventana™ acceptance angle



C = 1,024 x

*without AR coatings

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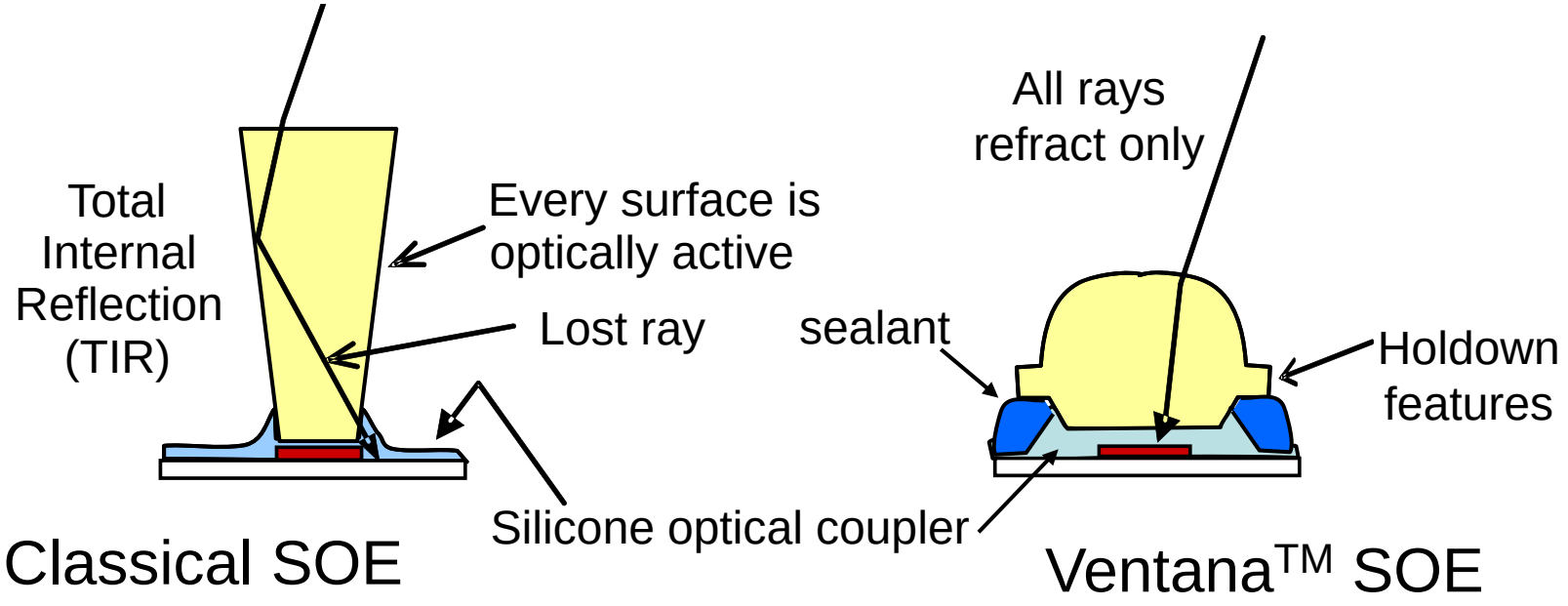
The Ventana™ reliability (可靠性)

The cell encapsulation:

- Cell is sensitive to contaminants in moisture.
- Ventana™ SOE allows for an excellent cell protection



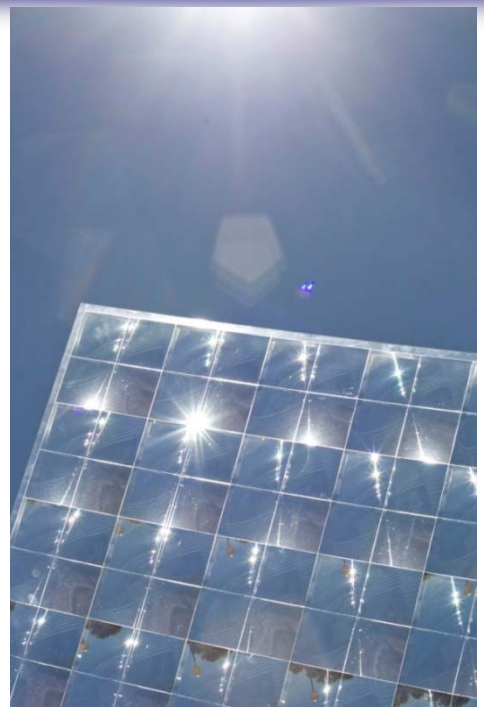
The Ventana™ reliability (可靠性)

POE:

- Evonik provides a 25 year warranty

SOE:

- The risk of UV solarization in Ventana™ is greatly reduced by splitting the incident beam into 4 channels.



Silicone:

- Ventana™ encapsulation can use catalist-free silicones, which are the most stable ones.

Conclusions

18th century Chinese vase (sold for $83 million in 2010)

谢谢！

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